4.1. Marina Flushing

Management Measure for Marina Flushing:

Site and design marinas such that tides and/or currents will aid in flushing of the site or renew its water regularly.

Management Measure Description

Water quality in a marina basin depends largely on how well the basin is flushed, which depends in turn on how well water circulates within the marina. Studies have shown that adequate flushing improves water quality in marina basins, reduces or eliminates water stagnation, and helps maintain biological productivity and aesthetic appeal. Flushing can reduce pollutant concentrations in a marina basin by anywhere from 70 percent to almost 90 percent over a 24-hour period.[1]

When a single number (e.g., 10 days) is given as the *flushing time* or *residence time* of a body of water (e.g., marina basin, harbor, or estuary), this number represents an average and doesn't accurately reflect what is happening inside the marina basin. Actually, flushing time in a marina basin can range from zero days at the boundary with the adjacent waterbody (at points of entry into the marina basin) to as much as several weeks within the marina basin at secluded locations or where in-water structures prevent water from circulating.

In a poorly flushed marina, pollutants tend to concentrate in the water and/or sediments. Pollutants and debris can collect in poorly flushed corners or secluded or protected spots in the same way that leaves collect in depressions in the ground where they are protected from wind. Stagnant, polluted water—with little biological activity, lifeless shorelines, and offensive odors—can be the consequence.

1 Cardwell and Koons, 1981; Tetra Tech, 1988.

In tidal waters, flushing is driven primarily by the ebb and flow of the tide. A large tidal volume relative to the total volume of a marina basin provides excellent flushing because each tidal exchange replaces a large amount of the marina basin water with "new" water from outside the marina basin. This condition is common on coastal waters in northern New England, the Pacific Northwest, and Alaska, where tidal circulation should adequately flush marinas.

In nontidal coastal waters, such as the Great Lakes, wind drives circulation in the water adjacent to a marina. The circulating water outside a marina basin can have a flushing effect on water within the marina if the speed, persistence, and direction of the wind create a strong enough current. In many situations wind-driven currents can provide adequate flushing of marina basins.

In river waters, with current flow, water usually moves into and out of the marina basin continuously unless the basin is built into the land or has only one small entrance channel.

The BMPs mentioned below are particularly applicable for incorporation into a marina's design at new and expanding marinas. Marinas with poor water quality that could be attributed to poor flushing might also benefit from using one or more of the following BMPS, as appropriate. Entrance channel design and wave protection structures must be designed with other factors in mind as well. Adequate protection from wave energies, episodic storm currents, and ice floes and shoreline erosion protection must be considered in the overall design strategy.

Applicability

This management measures primarily applies to new and expanding marinas.

Best Management Practices

♦ *Ensure that the bottom of the marina and the entrance channels are not deeper than adjacent navigable channels*

Flushing rates in marinas can be improved and maximized by proper design of entrance channels and the basin. Areas with minimal or no tides or poor circulation should have basin and channel depths designed to gradually increase toward open water to promote flushing.

Even where good flushing does occur, this alone does not guarantee that a marina's deepest waters will be renewed on a regular basis. As mentioned previously, deep canals and depressions much deeper than adjacent waters might not be adequately flushed by tidal action or wind-generated forces. Fine sediment and organic debris will collect in them, and low dissolved oxygen concentrations can result. In the warmer months when dissolved oxygen concentrations are normally low because of higher water temperatures, the even lower dissolved oxygen concentrations in these depressions can deteriorate water quality and hinder biological activity in the water.

♦ *Consider design alternatives in poorly flushed waterbodies to enhance flushing. For example, consider*

- An open design where a semienclosed design is not functional.
- Floating wave attenuators where fixed breakwaters are not functional.

When selecting a marina site and developing a design or when reconfiguring an existing marina, the need for efficient flushing of marina waters should be a prime consideration.

Where a poorly flushed location is the only one available or where a marina is already operational in such a location, special arrangements may be necessary to ensure adequate flushing. Selection of an open marina design may be considered. Open marina designs have no natural barriers to restrict the exchange of water between the larger waterbody and the marina basin. To accommodate both improved flushing and protection from wave energy, floating wave attenuators can be useful. Floating wave attenuators do not impede flushing because water exchange is not restricted by an underwater structure, yet the marina is protected from limited wave action. Floating wave attenuators can provide effective protection where waves do not usually exceed 3 feet, and open area designs can be a viable alternative where they do not leave a marina exposed to excessive wave action that could damage property and cause shoreline erosion.

♦ *Design new marinas with as few enclosed water sections or separated basins as possible to promote circulation within the entire basin.*

Overall flushing in a marina is a function of the number of separate basins in the marina. A marina in open water generally flushes better than a one-basin marina; a one-section marina, instead of square corners, can eliminate stagnant corner water and can help produce strong circulation in a marina basin. A marina in open water flushes better than a one-segment marina, a one-segment marina generally flushes better than a two-section marina, and so forth (Figure 4-1). Curved corners, instead of square corners, can eliminate stagnant corner water and can help produce strong circulation within a marina basin.

♦ *Consider the value of entrance channels in promoting flushing when designing or reconfiguring a marina.*

> There are situations where it may be necessary to have areas deeper than the rest of the marina basin. For example, Cove Haven Marina (Rhode Island) services large 12-meter America's Cup sailboats with deep keels and needs sufficiently deep water in and adjacent to the boat haul-out facility to do so. In this case, the state allows the marina to maintain this site dredged deeper than the rest of the marina (USEPA, 1996: *Clean Marinas—Clear Value*).

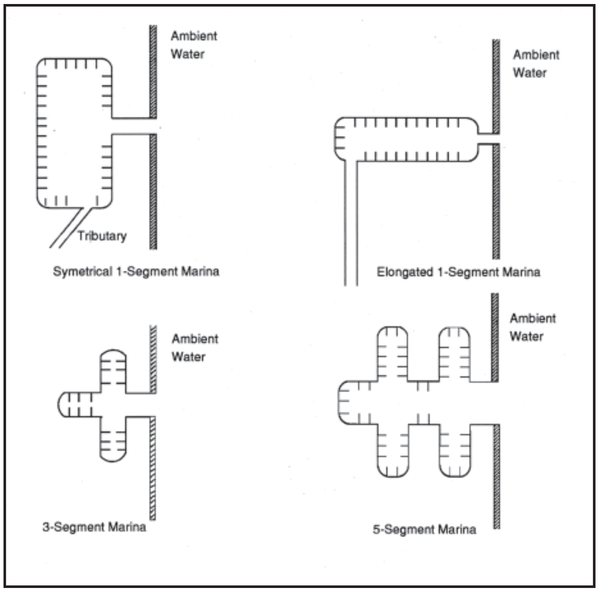

Figure 4-1. Example marina designs.

The alignment and number of entrance channels may affect flushing, along with many other site-specific factors. The following points generally hold true and should be considered when designing or reconfiguring a marina:

- Entrance channels that follow the natural channel alignment and have only gradual bends promote flushing.
- Where the tidal range is small, a wider entrance may promote flushing.
- Where the tidal range is large, a single narrow entrance channel may improve flushing.
- In tidal and nontidal waters, entrance channels aligned parallel to the direction of prevailing winds or water flow might enhance flushing.

The orientation and location of a solitary entrance might affect marina flushing rates and should be considered along with other factors that affect flushing. Consider the following points:

- In a square or rectangular marina basin, a single entrance at the center of a marina may promote flushing better than a single corner-located asymmetric entrance.
- In a circular marina basin, an off-center entrance channel might promote better circulation.

♦ *Establish two openings at the most appropriate locations within the marina to promote flow-through currents.*

Where water-level fluctuations are small (e.g., nontidal waters), alternatives in addition to the ones previously discussed can be considered to ensure adequate water exchange and to increase flushing rates. An elongated marina situated parallel to a tidal river may be adequately flushed by using two entrances to promote a flow-through current. A small outlet onto an adjacent waterbody can be opened solely to enhance flushing (Figure 4-2). Buried pipelines have been similarly used to promote flushing.

♦ *Consider mechanical aerators to improve flushing and water quality where basin and entrance channel configuration cannot provide adequate flushing.*

Where poor water quality throughout a marina basin or in secluded spots is a problem because of poor flushing, limited circulation, or other circumstances, mechanical aerators (such as those used for ice protection) might be helpful.

These devices can raise the level of dissolved oxygen in the water and circulate floating debris out of corners into the rest of the basin, where it can be flushed out naturally. Underwater air bubblers or submerged impeller-type motors can be effective during short-term episodes that might occur during the summer. In certain circumstances, such as in shallow and enclosed waters, water clarity improvement is often noted if artificial aeration is used.

Both compressed air and agitator systems work in fresh water, salt water, and brackish water. They do not work well in ice-covered rivers because river currents destroy bubble or flow patterns and because of the lack of heat. Thermal mixing of river water is a natural process, and a river that has formed an ice cover has already dissipated nearly all available heat.

Figure 4-2. Puerto Del Ray Marina (Puerto Rico) has an offshore rubble mound breakwater that protects the southeastern and eastern exposures of the marina. Two hundred feet of the southern breakwater was removed, creating a new south side breachway exit/enterance that is still well protected but now allows for greater circualtion in the basin. Water clarity improved after the alteration, and as a result new customers (a 3 percent increase for the marina) relocated to Puerto Del Rey Marina (USEPA, 1996: *Clean Marinas—Clear Value*).

Ice suppression systems available for marinas hinder ice formation by using compressed air bubblers or in-water agitators. Bubbler systems force air to entrain warmer bottom water into a rising plume, which reacts with and melts the underside of the ice sheet. Water agitators work on the basis of thermal reserves of basin waters and surface currents to prevent freezing.

BMP Summary Table 1 summarizes the BMPs for Marina Flushing mentioned in this guidance.

BMP Summary Table 2. WATER QUALITY ASSESSMENT MANAGEMENT

MANAGEMENT MEASURE: Assess water quality as part of marina siting and design.

APPLICABILITY: Primarily applies to the design of new and expanding marinas.

ENVIRONMENTAL CONCERNS: Water quality is assessed during the marina design phase to predict the effect of marina development on the chemical and physical health of the water and aquatic environment. Marina development can cause changes in flushing and circulation; and boat maintenance, boat operation, and the human activities in and around boats can be sources of solid and liquid wastes, pathogenic organisms, and petroleum compounds. The results of water quality predictions or sampling are compared to state or federal water quality standards. Water quality assessments for dissolved oxygen concentration and pathogenic organisms can be used as indicators of the general health of an aquatic environment. Water quality assessments can be useful in determining the suitability of a location for marina development, the best marina design for ensuring good water quality, and the causes and sources of water quality problems.

WATER QUALITY ASSESSMENT PRACTICES

Best Management Practice Examples	Marina Location & Usage	Benefits to Marina	Projected Environmental Benefits	Initial Cost Estimate	Annual Operation & Maintenance Cost Estimate	Notes
Use water quality sampling and/or monitoring to measure water quality conditions	Proposed marina basin/expansion site; generally recommended	MODERATE; can help determine whether a proposed marina will negatively affect water quality and suggest design alternatives; might be required	MODERATE to HIGH; can help determine if an area can sustain good water quality with a marina	HIGH, depends on type of tests and number or samples	NONE	Monitoring an area larger than just the marina is necessary to determine the source of water quality problems; gather existing data first; check with state and county agencies, U.S. Geological Survey (USGS).
Use a water quality modeling methodology to predict post-construction water quality conditions	Proposed marina basin; recommended for large new projects	MODERATE to HIGH; can cost less than sampling; can assist in choosing the best design; suitable for predicting circulation and wave damage exposure	MODERATE to HIGH; models can predict flushing and pollutant loads for many different marina designs	MODERATE to HIGH	NONE	Some models applicable to marinas are reviewed in Section 5.
Monitor water quality using indicators	Marina grounds and basin; universally recommended	HIGH to MODERATE; quickly provides information about the health of the water and aquatic habitat	HIGH; regular visual inspections help track changes, help identify potential problems before they become large	NONE	LOW to NONE	Appearance, clarity, and smell of water, abundance and appearance of aquatic plants, and appearance of sediments are all good indicators; very cost-effective; simple; requires little training.
Use rapid bioassessment techniques to monitor water quality	Marina basin; recommended where bioassessment protocols have been established	HIGH to MODERATE; provides information about the biological quality of marina waters.	MODERATE; can indicate water quality problems that might not be tested for in a water quality sampling program.	LOW; might have to train someone in aquatic invertebrate identification.	LOW	Cost-effective; not available for many waters

BMP Summary Table 1. (cont.) MANAGEMENT MEASURE FOR MARINA FLUSHING

Best Management Practice Example	Marina Location & Usage	Benefits to Marina	Projected Environmental Benefits	Initial Cost Estimate	Annual Operation & Maintenance Cost Estimate	Notes
Establish two openings at the most appropriate locations within the marina to promote flow-through currents	Entrance channels; recommended only where feasible	MODERATE to HIGH; flow-through circulation promotes good water	MODERATE to HIGH; entrance channels aligned with natural flow can increase flushing	EXPENSIVE	HIGH to EXPENSIVE; depending on degree of wave attenuation	More than one entrance channel may leave the marina too exposed
Consider mechanical aerators to improve flushing and water quality where basin and entrance channel configuration cannot provide adequate flushing	Marina basin; generally recommended for marinas with poor circulation	HIGH; useful to keep floating debris from collecting in corners; also can be used as ice control system in winter	HIGH; can quickly improve circulation and raise the dissolved oxygen concentration; improves water clarity	LOW - per unit; MODERATE to HIGH - bubbler system	LOW to MODERATE; depending on number of units and days used	Air bubblers or impeller motors are effective during short periods of low dissolved oxygen concentration, e.g., during a very hot period.